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(54) Liquid crystal composition.

(57) A liquid crystal composition includes three liquid crystal materials, each seleced from specified liquid crystal compounds. The composition has a low threshold voltage and a low viscosity.

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Liquid crystal composition

The present invention relates to a liquid crystal composition.

In conventional twisted nematic (TN) liquid crystal display devices used as display elements for electronic wristwatches or the like, liquid crystals including those having a high N-I (nematic-isotropic phase transition) point are mixed in nematic liquid crystals (Np liquid crystals) having a positive dielectric anisotropy ($\Delta\varepsilon$) so as to increase the N-I point. Such small liquid crystal devices are required to operate at a low voltage so as to simplify voltage source circuits and prolong the life of a battery.

The voltage for driving the display device must be sufficiently higher than a threshold voltage Vth of the liquid crystal material used. The threshold voltage is defined as the voltage applied to the liquid crystal material to change the amount of light (transmitted from the liquid crystal material) to a predetermined extent (i.e., 50%), at which the change in the transmitted amount is distinguishable with respect to the amount of light transmitted from the liquid crystal material when no voltage is applied thereto. The value of the threshold voltage is inherent to the liquid crystal material used. In order to drive the display device at a low voltage, therefore, a liquid crystal composition

having a low threshold voltage must be used.

Conventional liquid crystal compositions, however, have high threshold voltages. A conventional liquid crystal composition must be driven at a voltage of no less than about 1.5 V even when it is statically driven. When the liquid crystal composition is dynamically driven, a sufficiently higher voltage must be applied thereto. For example, when a dynamically driven liquid crystal display device is time-divisionally driven at a 1/2 duty, a common connection electrode is selected for every half of one-frame period and an effective voltage applied between the segment electrode and the common electrode is decreased. For this reason, in order to dynamically drive a liquid crystal display device which has a conventional liquid crystal composition, a high voltage of about 3 V must be applied in view of the decrease in the effective voltage value.

In short, a statically driven liquid crystal display device using the conventional liquid crystal composition is driven by a battery having an electromotive force of 1.5 V at least. However, a dynamically driven liquid crystal display device using the conventional composition must be driven by two batteries each having an electromotive force of 1.5 V or a large battery having an electromotive force of 3 V. As a result, the liquid crystal display device becomes large in size as a whole. The conventional dynamically driven liquid crystal display device can be driven by one battery having an electromotive force of 1.5 V when the battery voltage is boosted. For this purpose, however, a booster complicates the arrangement of the driving circuit of the liquid crystal display device.

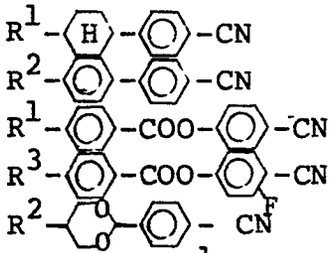
Furthermore, a threshold voltage and a viscosity of a conventional liquid crystal composition vary greatly in accordance with a change in temperature. At low temperatures, the threshold voltage is high and the composition cannot then be sufficiently driven at such

temperatures, thereby degrading display contrast. Under the same conditions, the viscosity of the composition is increased to prolong the response time. As a result, conventional liquid crystal compositions can be used only within a narrow operation temperature range.

It is, therefore, an object of the present invention to provide a liquid crystal composition which has a low threshold voltage Vth and has a wide operation temperature range.

In order to achieve the above object of the present invention, there is provided a liquid crystal composition comprising:

at least one first liquid crystal material selected from the group consisting of liquid crystal compounds represented by general formulas



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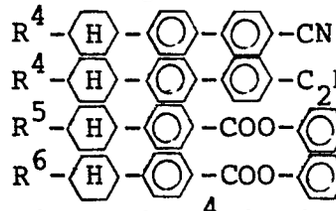
(wherein each R^1 is independently ethyl group, propyl group or butyl group, each R^2 is independently ethyl group, propyl group or pentyl group, and R^3 is ethyl group or propyl group);

at least one second liquid crystal material selected from the group consisting of liquid crystal compounds represented by general formulas



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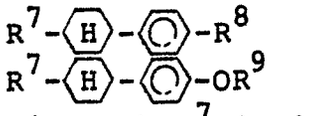
(wherein each R^4 is independently propyl group or pentyl group, R^5 is ethyl group or pentyl group, and R^6 is propyl group or butyl group); and

at least one third liquid crystal material selected from the group consisting of liquid crystal compounds represented by general formulas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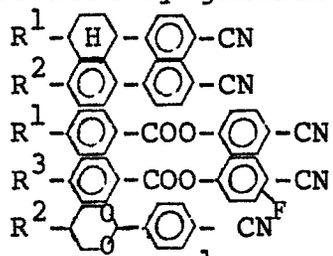
(wherein each R^7 is independently propyl group or pentyl group, R^8 is ethyl group or propyl group, and R^9 is methyl group, ethyl group, or butyl group).

In general, the first to third liquid crystal materials are used in the amounts of 5 to 70% by weight, 15 to 40% by weight and 5 to 30% by weight, respectively, based on the total weight of the liquid crystal composition.

The present inventors made extensive studies to find a liquid crystal composition which has a low threshold voltage Vth and can therefore be dynamically driven at a low application voltage, but which has a wide operation temperature range. The present inventors found that the prescribed object could be achieved by combining a specific liquid crystal compound which lowers the threshold voltage, another specific liquid crystal compound which maintains a liquid crystal phase even at a high temperature, and still another liquid crystal compound whose viscosity is low and which does not increase the threshold voltage.

The liquid crystal composition of the present invention comprises three liquid crystal materials as described above.

The first liquid crystal material is selected from the group consisting of liquid crystal compounds represented by general formulas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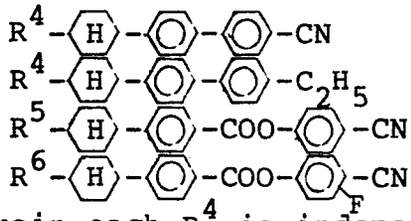
(wherein each R^1 is independently ethyl group, propyl group or butyl group, each R^2 is independently ethyl group, propyl group or pentyl group, and R^3 is ethyl group or propyl group). A mixture of two or more of

these liquid crystal compounds can be used.

The first liquid crystal material has a very large positive dielectric anisotropy $\Delta\varepsilon$ (e.g., + 10 or more) and decreases the threshold voltage Vth of the resultant liquid crystal composition. In particular, the compound represented by general formula (IV) has a positive dielectric anisotropy $\Delta\varepsilon$ of +20 or more (however, viscosity is high).

The second liquid crystal material is selected from the group consisting of liquid crystal compounds represented by general formulas



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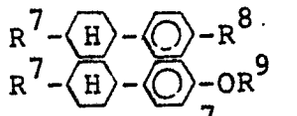
(wherein each R^4 is independently propyl group or pentyl group, R^5 is ethyl group or pentyl group, and R^6 is propyl group or butyl group). A mixture of two or more of these liquid crystal compounds can be used.

The second liquid crystal material is a high-temperature liquid crystal having a high N-I point and can maintain the liquid crystal phase up to a high temperature of 160°C or more. In general, a liquid crystal having a high N-I point has a high viscosity. However, the second liquid crystal material used in the present invention has a relatively low viscosity (e.g., 90 cP or less at 20°C). In particular, the compound represented by general formula (VII) has a viscosity of 20 cP at 20°C. The compound represented by general formula (IX) has a large positive dielectric anisotropy $\Delta\varepsilon$ ($\Delta\varepsilon$ = + 20), and therefore, the threshold voltage Vth of the resultant liquid crystal composition containing this compound can be decreased.

The third liquid crystal material used in the present invention is selected from the group consisting of liquid crystal compounds represented by general formulas



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(wherein each R^7 is independently propyl group or pentyl group, R^8 is ethyl group or propyl group, and R^9 is methyl group, ethyl group, or butyl group). A mixture of two or more of these compounds can be used.

The third liquid crystal material has a very low viscosity (10 cP or less at 20°C) and a positive dielectric anisotropy $\Delta\varepsilon$ close to zero. Therefore, the third liquid crystal material serves to decrease the viscosity of the resultant composition without increasing the threshold voltage very much. The third liquid crystal material guarantees the operation of the liquid crystal composition at a low temperature. It should be noted that R^1 to R^9 in general formulas (I) to (XI) preferably have normal structures.

The liquid crystal composition of the present invention comprises the first, second and third liquid crystal materials as noted above. The mixing ratio of these liquid crystal materials is preferably as follows.

The first liquid crystal material is used in the amount of 5 to 70% by weight, preferably 40 to 55% by weight, based on the total weight of the first, second and third liquid crystal materials. When liquid crystal compounds represented by formula (I) and/or formula (II) are used, the mixing ratio more preferably falls within the range of 10 to 30% by weight. When a liquid crystal compound represented by general formula (III) is used, the mixing ratio more preferably falls within the range of 5 to 30% by weight. When liquid crystal compounds represented by general formula (IV) and/or general formula (V) are used, the mixing ratio more preferably falls within the range of 5 to 40% by weight.

The second liquid crystal material is used in the amount of 15 to 40% by weight based on the total weight of the first, second and third liquid crystal materials. The second liquid crystal material is preferably used

in the amount of 25 to 35% by weight.

The third liquid crystal material is used in the amount of 5 to 30% by weight based on the total weight of the first, second and third liquid crystal materials. The third liquid crystal material is preferably used in the amount of 15 to 25% by weight.

The liquid crystal composition having a combination of three specific liquid crystal materials has a low threshold voltage Vth (the composition can be dynamically driven at an application voltage of about 1.5 V) and has a low viscosity (40 cP or less at 20°C). In addition, the threshold voltage Vth and the viscosity are only slightly changed in accordance with changes in ambient temperature, so that the composition has a wide operation temperature range. Furthermore, the liquid crystal composition of the present invention has an N-I point of 55°C or more and a C-N point (crystal-nematic phase transition) point of 0°C or less.

The present invention will be described in detail by way of examples.

Example

Three groups of liquid crystal compounds were mixed in the amounts (% by weight) as given in the table below. Threshold voltages Vth at 25°C, N-I points, C-N points, and viscosities (cP; centipoise) at 20°C of the resultant liquid crystal compositions were measured. The results are shown in the table.

Incidentally, the respective liquid crystal compounds were measured in % by weight as given in the table and poured into a glass container. After the container was evacuated and nitrogen gas was introduced, the container was sealed, thereby obtaining a nitrogen atmosphere. The glass container was dipped in an oil bath at a temperature of 80°C, thereby heating and convecting the liquid crystal compounds in the glass container, thus mixing the compounds.

Table

Liquid crystal compound		Example 1	Example 2	Example 3	Example 4	Example 5
First liquid crystal material	C_2H_5-(H)-(O)-CN	-	5	-	-	-
	C_3H_7-(H)-(O)-CN	17	10	-	18	18
	C_2H_5-(O)-(O)-CN	-	-	15	-	-
	C_2H_5-(O)-COO-(O)-CN	13	15	15	14	14
	C_2H_5-(O)-COO-(O)-CN (F)	6	8	9	9	9
	C_3H_7-(O)-COO-(O)-CN (F)	8	10	9	9	9
Second liquid crystal material	C_5H_{11}-(H)-(O)-(O)-CN	-	7	8	-	4
	C_5H_{11}-(H)-(O)-COO-(O)-CN	5	-	-	4	-
	C_3H_7-(H)-(O)-COO-(O)-CN (F)	8	10	7	9	9
	C_5H_{11}-(H)-(O)-(O)-C_2H_5	19	-	18	16	16
	C_3H_7-(H)-(O)-(O)-C_2H_5	-	15	-	-	-
Third liquid crystal material	C_3H_7-(H)-(O)-C_2H_5	6	-	-	10	10
	C_5H_{11}-(H)-(O)-C_3H_7	-	10	7	-	-
	C_3H_7-(H)-(O)-OC_2H_5	18	10	12	11	11
Physical properties	Vth at 25°C (Volt)	1.27	1.15	1.10	1.12	1.14
	N-I point (°C)	66.1	60.5	61.2	60	59.5
	C-N point (°C)	0°C or lower	0°C or lower	0°C or lower	0°C or lower	0°C or lower
	Viscosity at 20°C (cP)	27	32	35	29	27

As is apparent from the above table, the liquid crystal compositions of Examples 1 to 5 have low threshold voltages Vth of 1.10 V to 1.27 V. These compositions can be time-divisionally driven at a low application voltage of about 1.5 V. The compositions have high N-I points of 59.5°C to 66.1°C and low C-N points of 0°C or lower. At the same time, the viscosities of the resultant compositions are low, so that they have a wide operation temperature range. Therefore, the liquid crystal compositions of Examples 1 to 5 can be driven at a high response speed without degrading display contrast.

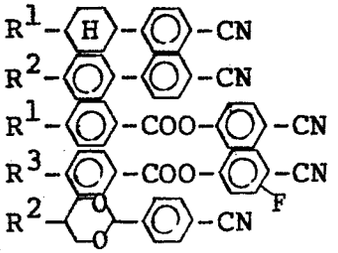
Even if an optically active material such as a chiral nematic liquid crystal is added to the liquid crystal compositions of the present invention, the characteristics of the compositions will not change. The liquid crystal compositions of the present invention have a positive dielectric anisotropy and are mainly used in TN liquid crystal display devices. Even if a dichroic dye is added to the liquid crystal compositions of the present invention, the characteristics of the compositions will not change, so that they can also be used for GH (guest-host) liquid crystal display devices.

The liquid crystal composition according to the present invention is sealed between a pair of electrodes at least one of which is transparent. A drive voltage is applied between the pair of electrodes to perform various display modes.

Claims:

1. A liquid crystal composition comprising:

at least one first liquid crystal material selected from the group consisting of liquid crystal compounds represented by general formulas



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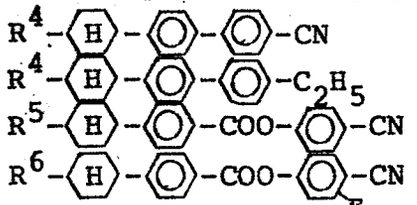
...(III)

...(IV)

...(V)

(characterized in that each R^1 is independently ethyl group, propyl group or butyl group, each R^2 is independently ethyl group, propyl group or pentyl group, and R^3 is ethyl group or propyl group);

at least one second liquid crystal material selected from the group consisting of liquid crystal compounds represented by general formulas



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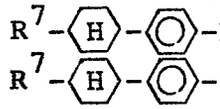
...(IX)

(characterized in that each R^4 is independently propyl group or pentyl group, R^5 is ethyl group or pentyl group, and R^6 is propyl group or butyl group); and

at least one third liquid crystal material selected from the group consisting of liquid crystal compounds represented by general formulas



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(characterized in that each R^7 is independently propyl group or pentyl group, R^8 is ethyl group or propyl group, and R^9 is methyl group, ethyl group, or butyl group).

2. A composition according to claim 1, characterized in that said first to third liquid crystal materials are used in amounts of 5 to 70% by weight, 15

to 40% by weight and 5 to 30% by weight, respectively, based on a total weight of said liquid crystal composition.

3. A composition according to claim 2, characterized in that said first liquid crystal material comprises at least one compound selected from the compounds represented by general formulas (I) and (II) and is used in an amount of 10 to 30% by weight.

4. A composition according to claim 2, characterized in that said first liquid crystal material comprises the compound represented by general formula (III) and is used in an amount of 5 to 30% by weight.

5. A composition according to claim 2, characterized in that said first liquid crystal material comprises at least one compound selected from the compounds represented by general formulas (IV) and (V) and is used in an amount of 5 to 40% by weight.

6. A composition according to claim 1, characterized in that said first liquid crystal material comprises at least one compound selected from the compounds represented by general formulas (I), (III) and (IV).

7. A composition according to claim 6, characterized in that said first to third liquid crystal materials are used in amounts of 40 to 55% by weight, 25 to 35% by weight, and 15 to 25% by weight, respectively.

8. A composition according to claim 1, characterized in that said composition has a threshold voltage of not more than about 1.5 V.

9. A composition according to claim 1, characterized in that said composition has a nematic-isotropic phase transition point of not lower than 55°C.

10. A composition according to claim 7, characterized in that said composition has a crystal-nematic phase transition point of not higher than 0°C.

11. A composition according to claim 8, characterized in that said composition has a viscosity of not more than 40 centipoises at 20°C.